SMART Initiative

Science-informed Machine Learning to Accelerate Real Time (SMART) Decisions in Subsurface Applications

U.S. DEPARTMENT OF ENERGY

NATIONAL ENERGY TECHNOLOGY LABORATORY

SMART Initiative

Primary Goals

Real-Time Visualization
"CT" for the Subsurface

Rapid Prediction
Virtual Learning

Real-Time Forecasting
"Advanced Control Room"

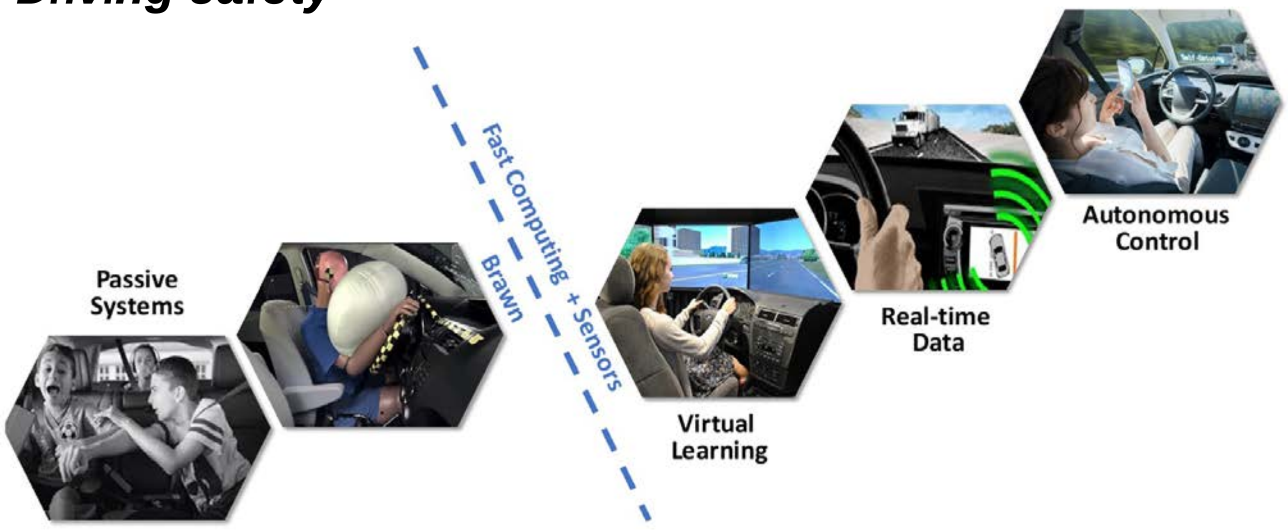
Technical Team

Carnegie Mellon University
Los Alamos National Laboratory
National Energy Technology Laboratory
Battelle
EERC University of North Dakota
Lawrence Livermore National Laboratory
Colorado School of Mines
Oak Ridge National Laboratory
PennState
The University of Utah
Pacific Northwest National Laboratory
Bureau of Economic Geology
Sandia National Laboratories
Illinois University of Illinois at Urbana-Champaign
Berkeley Lab

Science-informed Machine Learning to Accelerate Real Time (SMART) Decisions in Subsurface Applications

Transformational Experience

Driving Safety



Transformational Experience

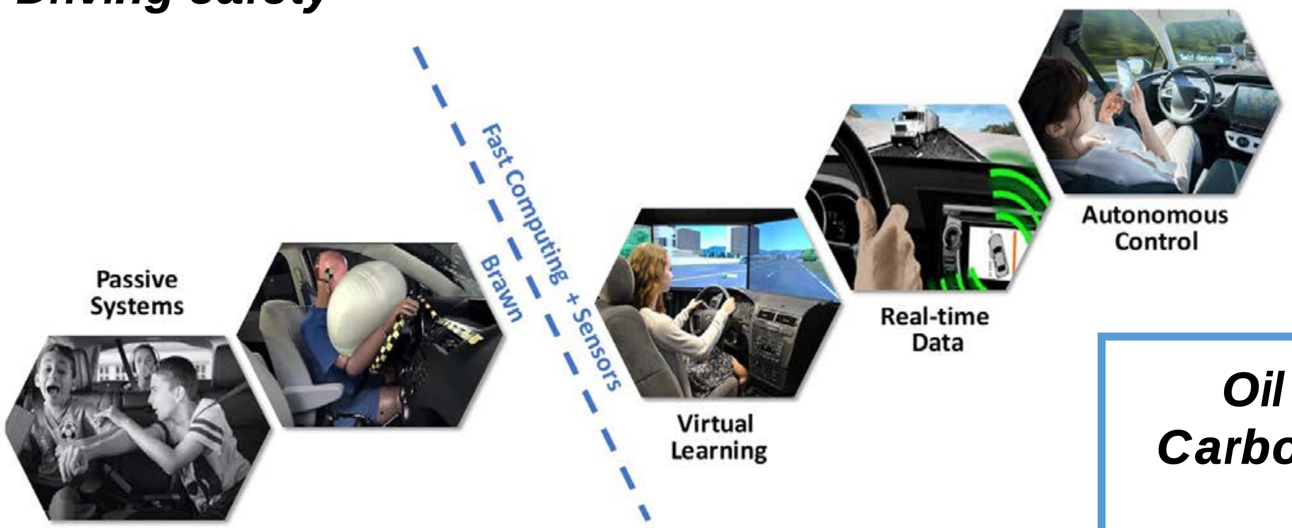
Pattern Recognition

Autonomous Monitoring

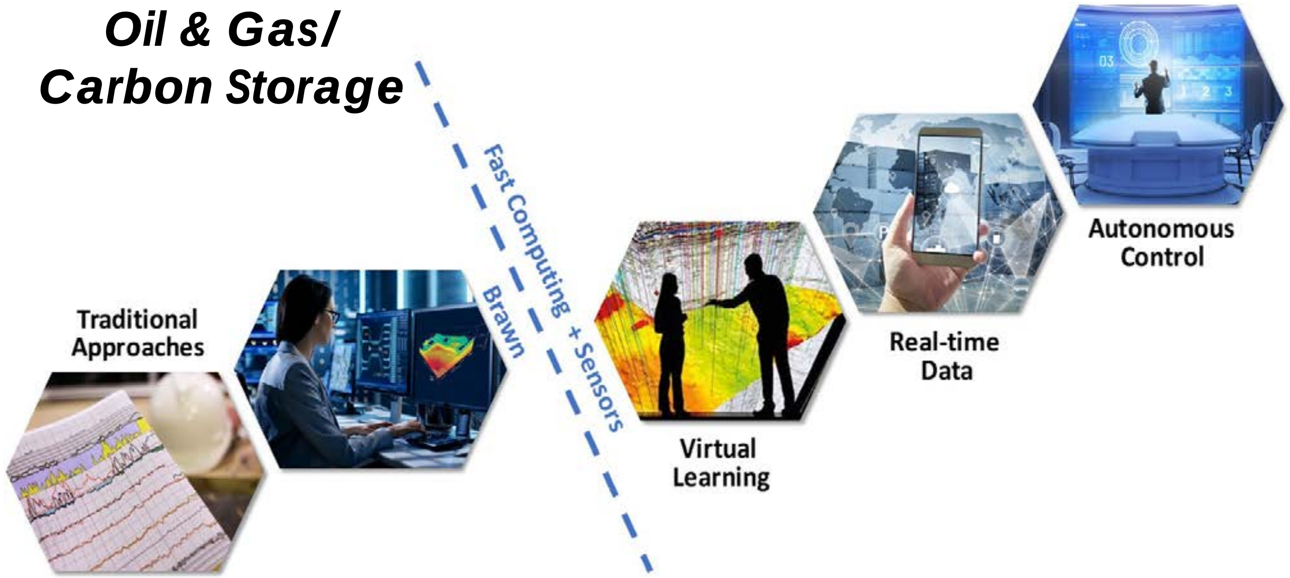
Virtual Reality Learning

Autonomous Control

Driving Safety



Oil & Gas/ Carbon Storage



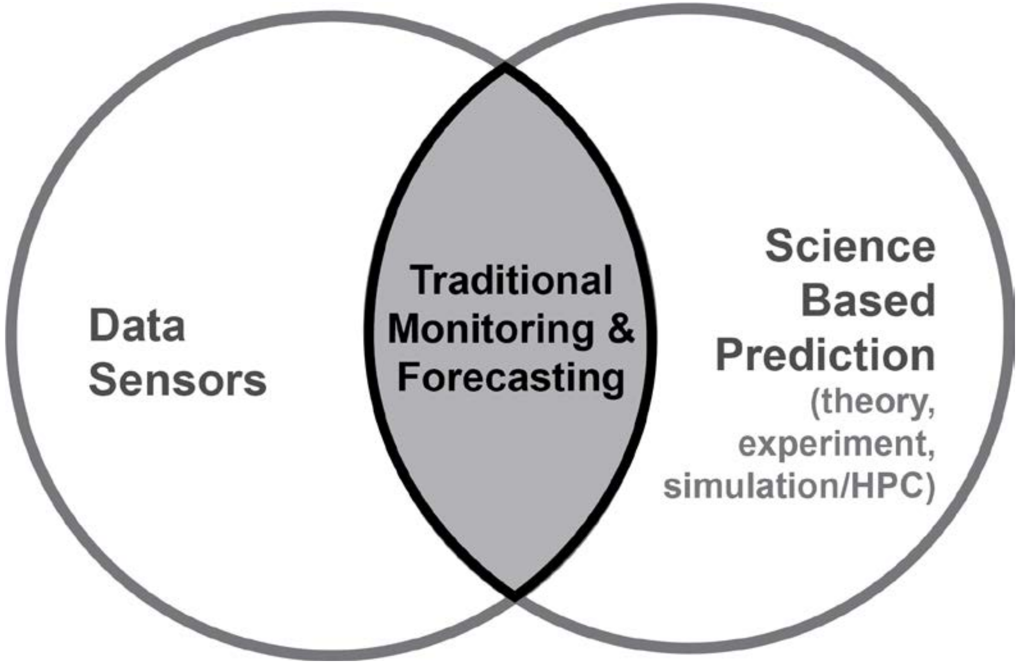
SMART Initiative

- **S**cience-Informed
- **M**achine Learning
- **A**ccelerating
- **R**eal
- **T**ime Decisions for Subsurface Applications

Programmatic Must-Haves…

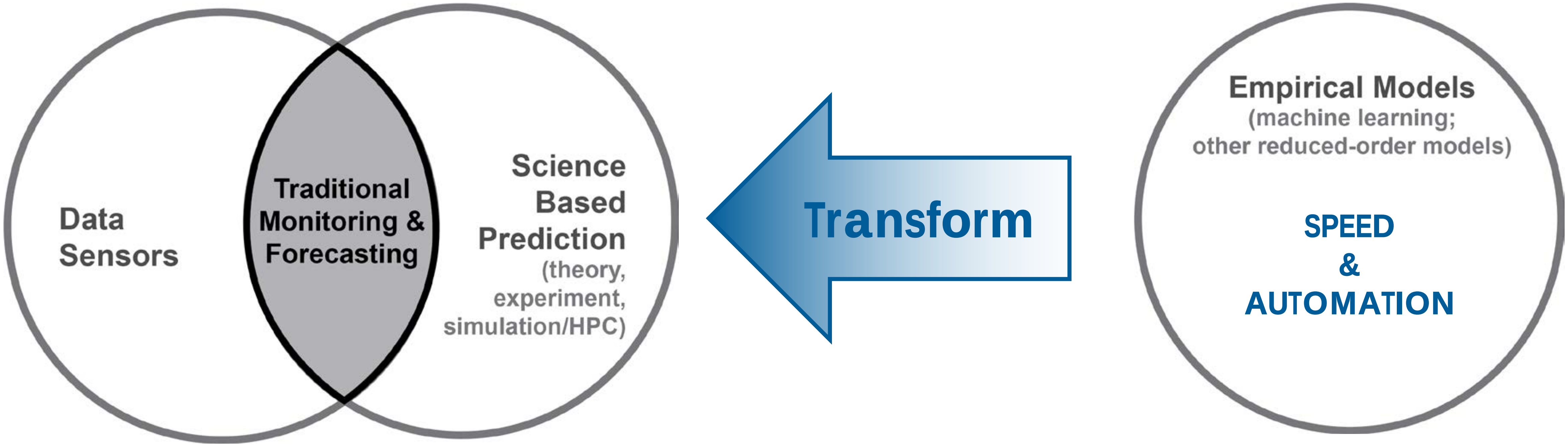
1. Transformational Products & Application(s)
2. Quantifiable Goals
3. Early Wins
4. Industry Buy-in
5. Leverage Existing Capabilities

How can machine learning transform subsurface operations?

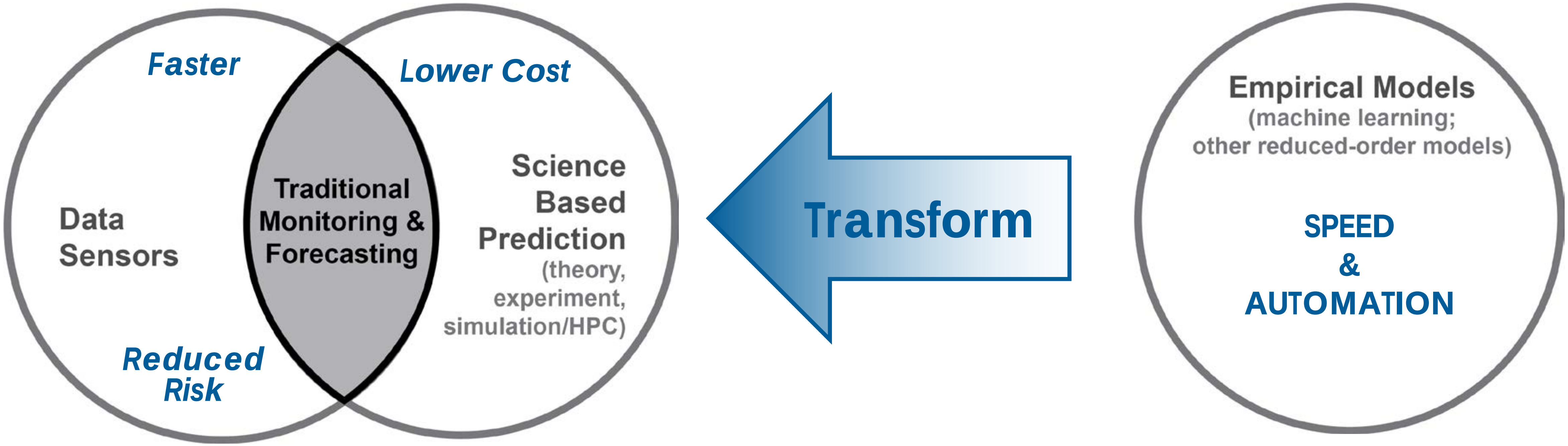


Traditional approach

How can machine learning transform subsurface operations?



How can machine learning transform subsurface operations?



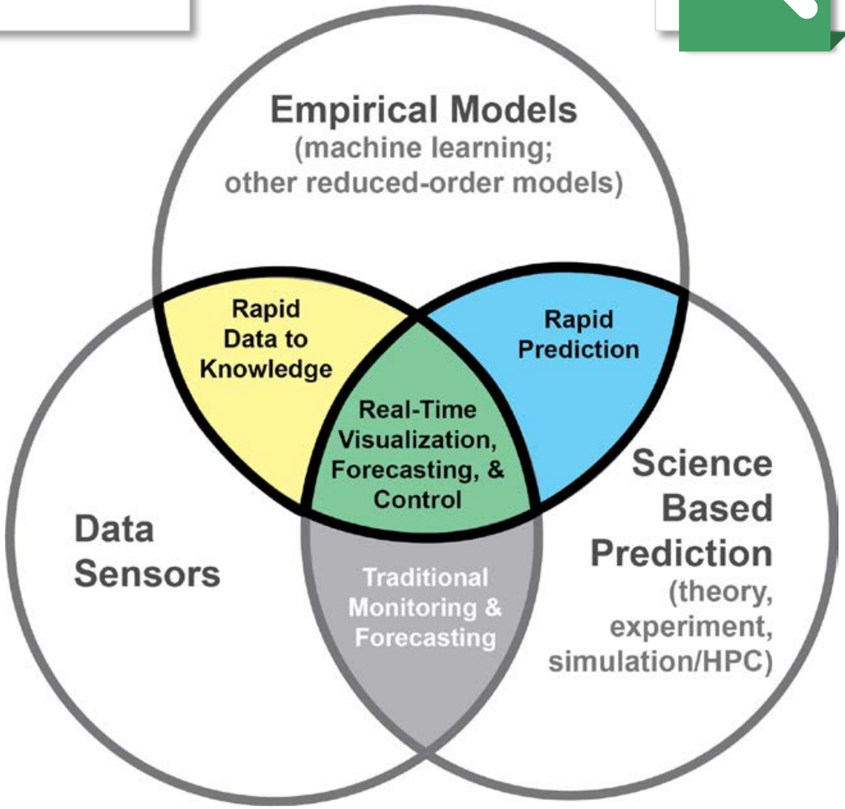
Confluence of Data, Computational Capability, and Machine Learning

Real-Time Visualization
"CT" for the Subsurface

Real-Time Forecasting
"Advanced Control Room"

Rapid Data to Knowledge
Autonomous Monitoring

Rapid Prediction
Virtual Learning



Current and Prior Fossil Energy Investments Enabling Machine Learning for the Subsurface

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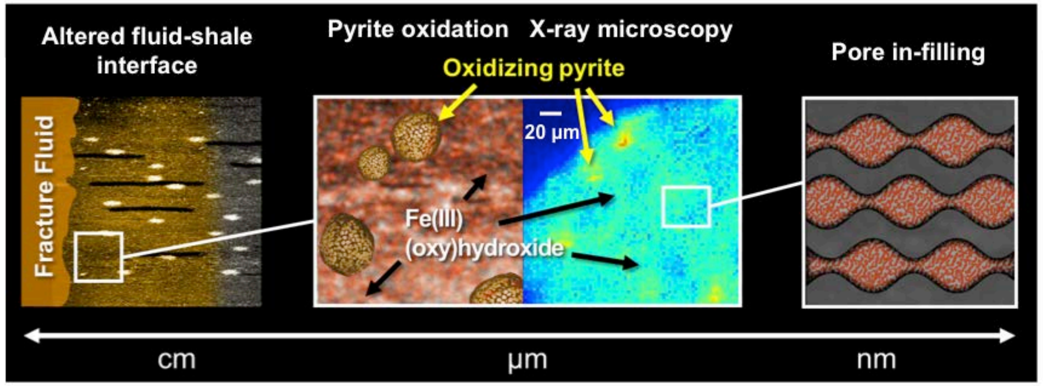

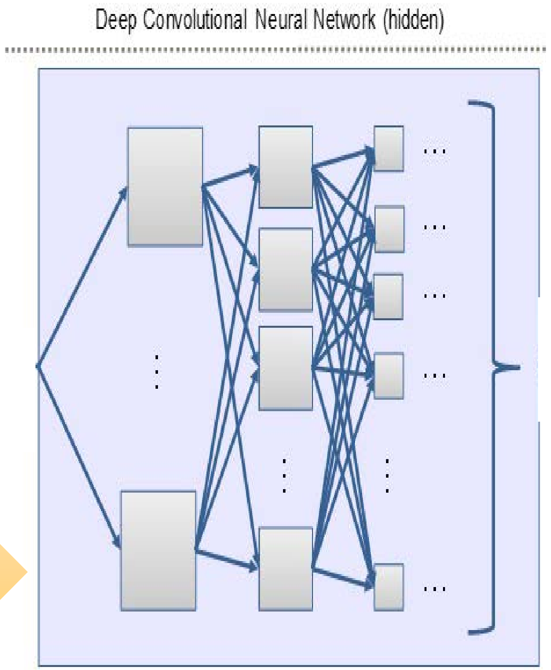

Fundamental Studies

Industry collaborations

Academia

DOE Labs

Field Laboratories

Data-Driven Approaches

More than 40 recent field projects

Real-Time Visualization

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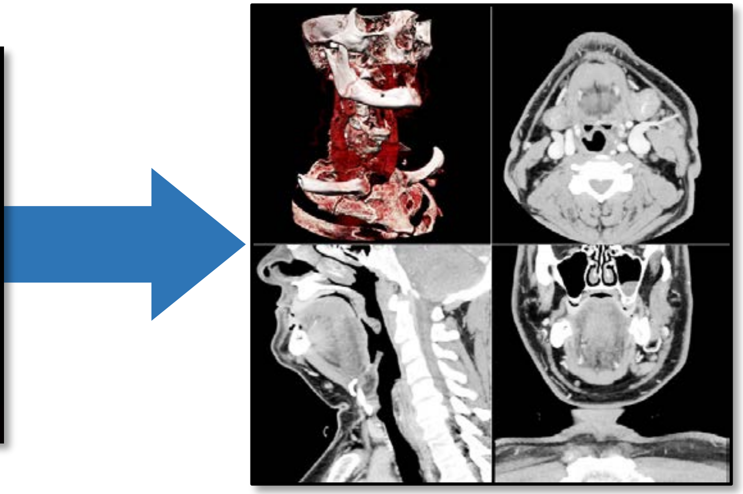
Real-Time Visualization
"CT" for the Subsurface

Vision: Transform reservoir management via dramatic improvements in subsurface visualization, exploiting ML to achieve speed and enhanced detail.



Three Imaging Targets

1. **Rock and fluid Properties**
2. **Pressure/stress**
3. **Faults and fracture networks**

Potential Technology Pathways

- **Joint inversion**
- **Multi-INT**
- **Tonal-Noise** Tomography

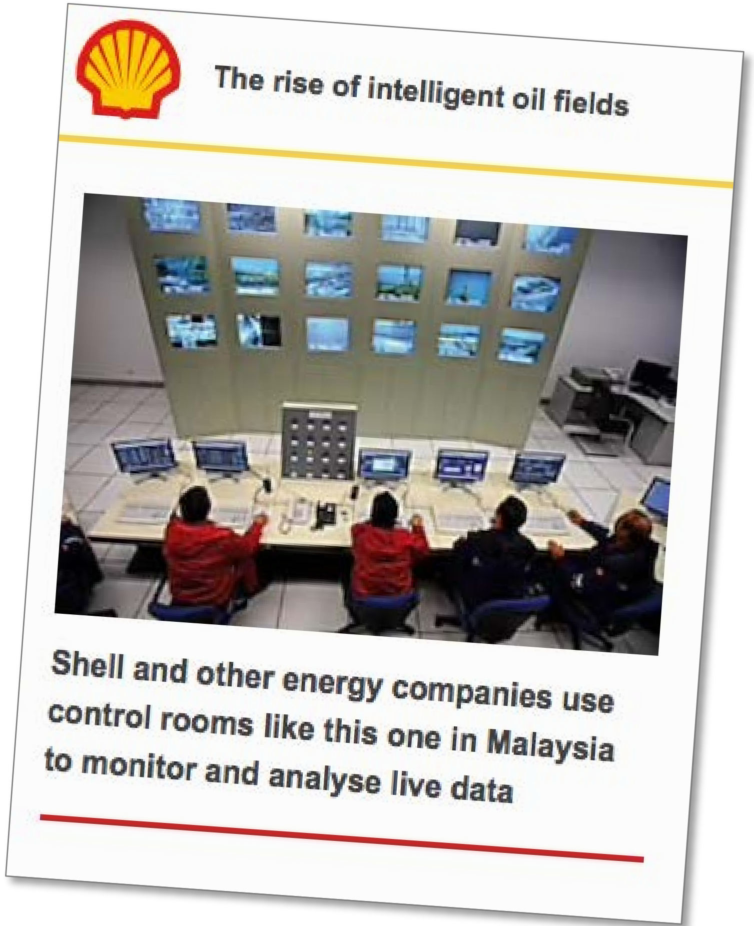
Real-Time Forecasting

Real-Time Forecasting
"Advanced Control Room"

Vision: Transform "human-in-the-loop" decisions on reservoir management by rapid visualization of forecasted behavior for different operational decisions.

Potential Operational Decisions

- How to adjust production rates and volumes in multiple wells to maximize recovery, sweep efficiency, …
- **How to adjust CO_2 injection & brine production in multiple wells to maximize storage and minimize pressure plume**
- When and how to refrack an unconventional to increase total recovery



Shell.com

Virtual Learning

Rapid Prediction
Virtual Learning

Vision: Enable a virtual learning environment for exploring and testing strategies to optimize reservoir development, management, & monitoring prior to field activities.

Virtual learning means experiential learning in a computer based environment that responds to a user's actions in real time, simulating the behavior of the subsurface system based on physics-based knowledge.

Physics-based knowledge means that the relevant subsurface processes must be known, well characterized, and able to be simulated with high fidelity.

Real-time is enabled by (1) coupling the high fidelity simulations with rapid, empirical methods (e.g., machine learning) and (2) exploiting developments for rapid visualization gaming environments.

Visualization Capabilities

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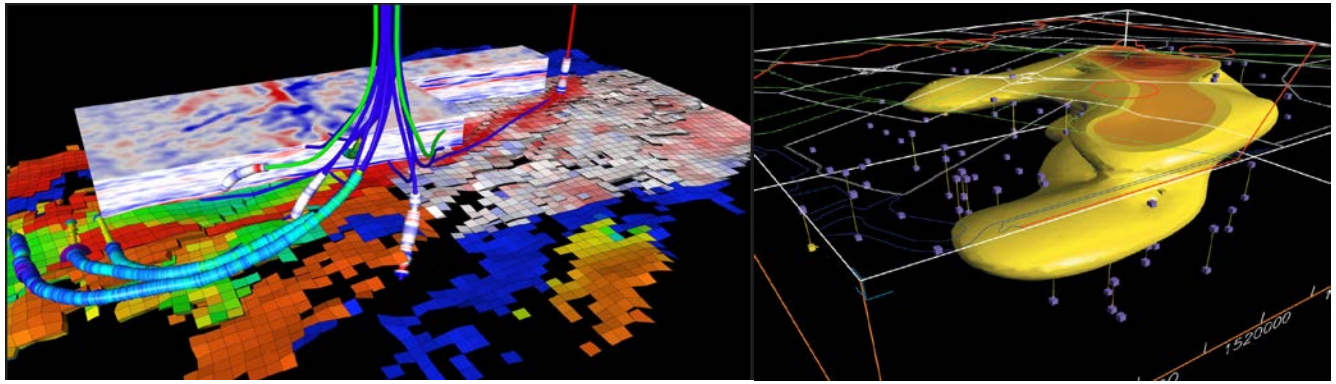
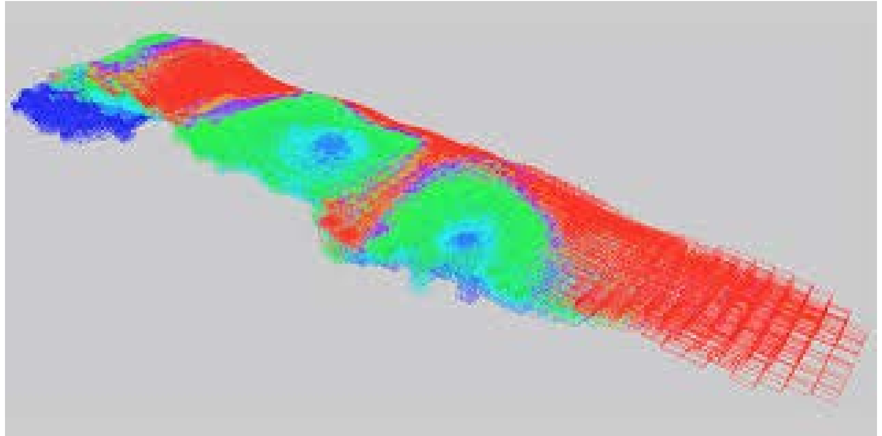
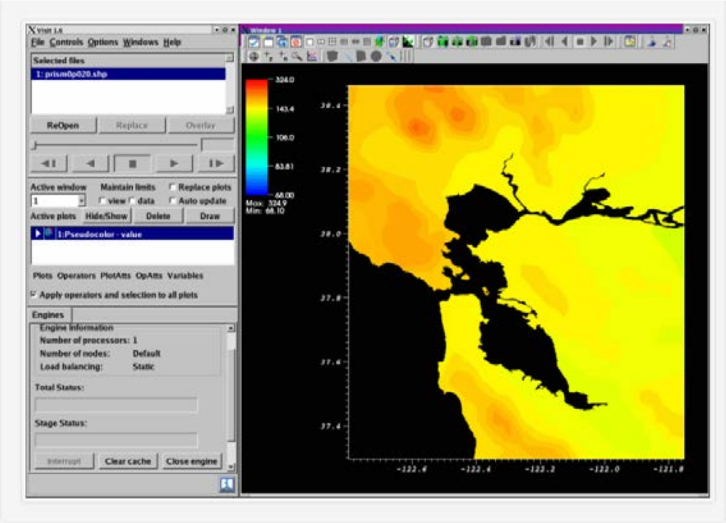
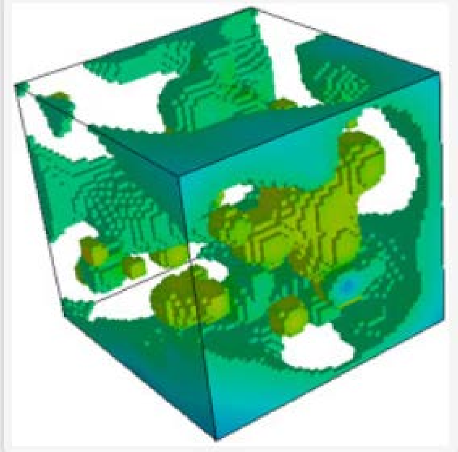


Dynamic Graphics



GEM

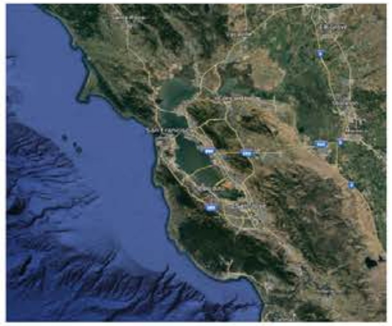




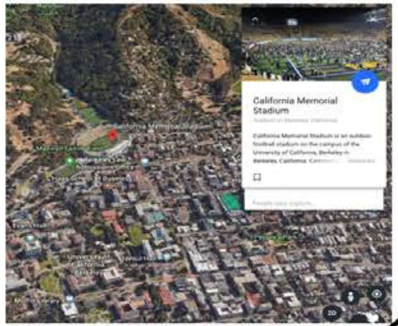
VisIT

Analogy for new visualization functionality

Scale too fine for planning route, but useful for determining if and why you would want to go



Scale too coarse for planning route to stadium, but useful for setting context of where in the world you are going to be



Target scale : maps useful for planning route to stadium

Decreasing Scale

Conceptual approach

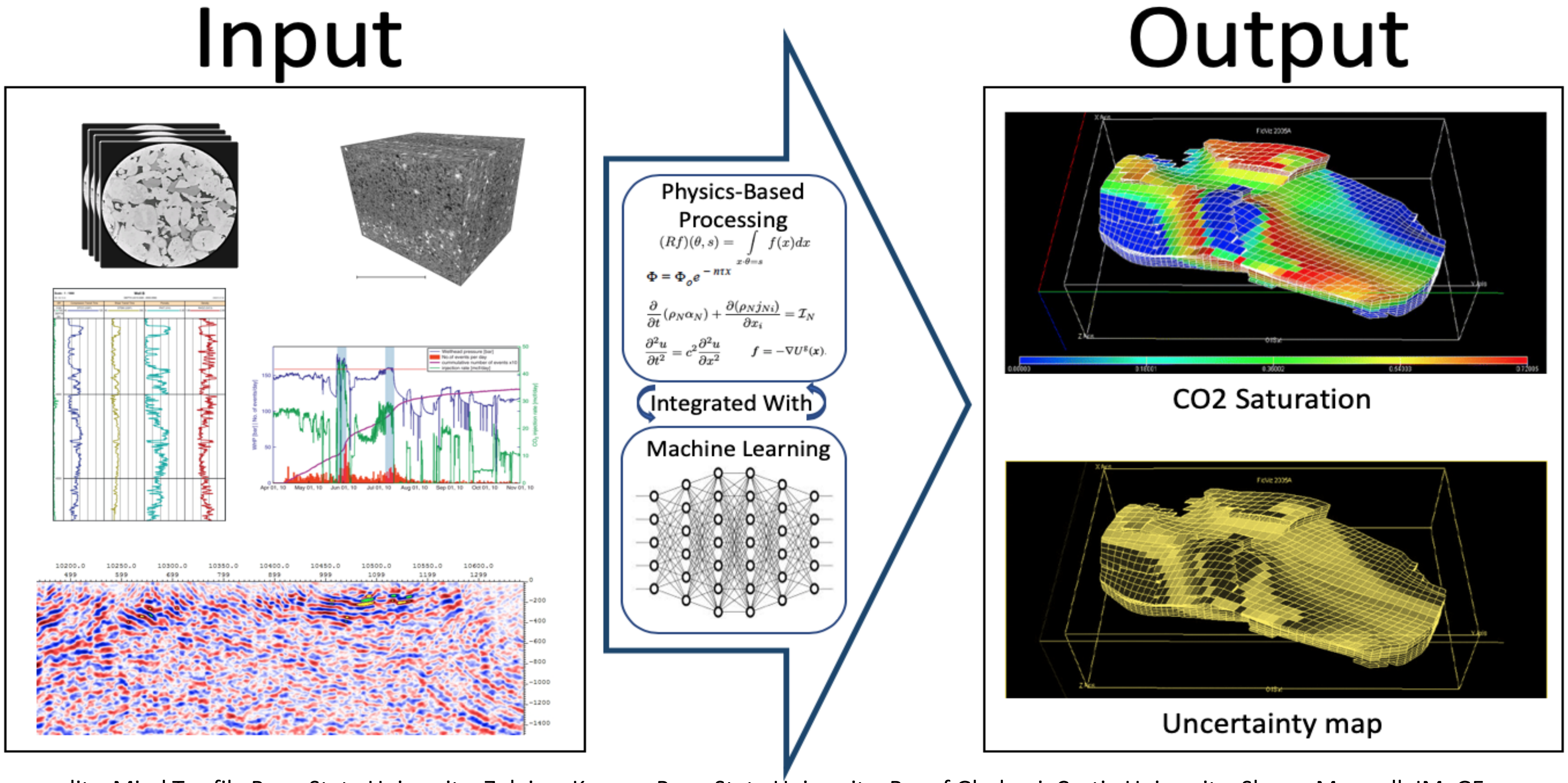


Image credits: Miral Tawfik, Penn State University; Zuleima Karpyn, Penn State University; Raoof Gholami, Curtin University; Shawn Maxwell, IMaGE: Itasca Microseismic and Geomechanical Evaluation; Fathom Geophysics; Shuttersock; Gholamreza Khademi, Cleveland State University

Goals for new visualization capabilities

- **Incorporates data and prediction**
  - Fast and accurate
- **Both static and dynamic features**
- **Visualizes uncertainty**
- **Incorporates different scales**
- **Intuitive for the non-technical person**

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What functionality do you need?

Thank You!

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CONTACT:

Grant Bromhal

Grant.Bromhal@netl.doe.gov